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RDX/CALCIUM-STEARATE BINARY SYSTEM EXPLOSIVE SENSITIVITY CALIBRATION

15 MAY 1963

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UNITED STATES NAVAL ORDNANCE LABORATORY, WHITE OAK, MARYLAND

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RDX/CALCIUM-STEARATE BINARY SYSTEM EXPLOSIVE SENSITIVITY CALIBRATION

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ABSTRACT: The Small Scale Gap Test sensitivity and output of RDX/Calcium-Stearate mixtures ranging from 0.59% to 23.75% Calcium Stearate have been determined for 4, 8, 16, 32 and 64 KPSI consolidating pressures. By choice of pressure and composition changes can be made with sensitivities from 3.4 to 7.8 DBg shock sensitivities. Although these mixtures can be used to satisfy the immediate needs for explosives for the VARICOMP measurement of weapon explosive train safety and reliability, explosive systems should be developed wherein composition control to obtain specific sensitivity and output is less critical.

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The VARICOMP method of penalty testing has been developed to permit demonstration of the high detonation-transfer safeties and reliabilities that are needed in modern weapon system explosive trains. A necessary adjunct of the VARICOMP method is a supply of explosive compounds or mixtures with sensitivities that can be selected in relation to the particular explosive system being studied.

The present report deals with the calibration, at the request of and funded by NOL, Corona, of an RDX/Calcium-Stearate binary system used for VARICOMP testing. The information is of interest to those who will be using the specific compositions from which the samples were taken and to those who are considering the possibility of utilizing the VARICOMP process. From this report can be obtained an idea of the scope of the work needed to calibrate a VARICOMP explosive series.

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REFERENCES

1. J. N. Ayres, L. D. Hampton, I. Kabik, A. D. Solem, "VARICOMP, A Method for Determining Detonation-Transfer Probabilities", NAVWEPS Report 7411, 30 June 1961
2. J. N. Ayres, "Standardization of the Small Scale Gap Test", NAVWEPS Report 7342, 16 January 1961.

RDX/CALCIUM STEARATE BINARY SYSTEM EXPLOSIVE SENSITIVITY CALIBRATION

Introduction

1. The VARICOMP[1] method of detonation-transfer probability assessment is based on the use of explosives of known sensitivities and/or outputs. For instance, if it can be shown that detonation will transfer with a known probability into a desensitized acceptor explosive, then logically the probability of transfer into a non-desensitized acceptor explosive under the same conditions will be higher. If the relative sensitivities of the explosives are known, it is possible with limited testing to determine the points of extremely high detonation transfer probabilities of a given weapon utilizing the non-desensitized explosive.

2. Direct determination of high firing probabilities by actual firing of weapons requires prohibitively large weapon samples. The VARICOMP method has been used to predict, with less than 100 shots, (mostly in simulated hardware) reliabilities in excess of 99.99% at better than 95% confidence. A direct observation of this performance level and confidence would require in excess of 10,000 trials.

3. The VARICOMP method requires the use of explosive charges of two or more controllable and differing sensitivities (or outputs). For the measurement of fuze explosive train detonation transfer probabilities a fifteen-member series of RDX/Calcium-Stearate mixtures has been prepared, ranging from 0.59 to 23.75% calcium stearate. The calcium stearate additive acts both as a desensitizer and as a binder for pelletizing. In general, the greater the calcium stearate content the less sensitive and the more compressible the mixture.

4. It is the purpose of this report to present the experimental data and to show the interrelationships between consolidating pressure, charge density, composition, and sensitivity of the RDX/calcium stearate binary explosive system. A close inspection of the data reveals certain minor inconsistencies which it is believed could be remedied by redetermination of the chemical composition of certain of the mixes. Even without these redeterminations the calibrations permit full use of the various mixes in VARICOMP testing.

(1) References are on page iv.

Preparation of the Explosive

5. The advisory information in Appendices A and B was furnished to the explosives manufacturer (Holston Ordnance Works) for the preparation and chemical analysis of the mixes. The manufacturer was limited by his available equipment to about 100 pounds of product per run. For orders greater than 100-pounds, 100 pound sub-batches were blended. A sample was taken of each sub-batch for chemical analysis and to permit future sensitivity testing.

6. Certain sub-batches were not analyzed. However, all samples (both batch and sub-batch) which were received at NOL were given unique identification numbers. Appendix C is a compilation of batch and sub-batch identification and analytical information.

Sensitivity Testing

7. The sensitivity of each of the fifteen main (composite) batches was determined using the Small Scale Gap Test.[2] Twenty bodies were loaded at each of five consolidating pressures: 4.0, 8.0, 16.0, 32.0, and 64.0 K psi. Two of the bodies at each of the five pressures were fired with no attenuation between the donor and acceptor. The average dent output of each pair of zero-gap shots was reported as the output. The eighteen shots remaining in each group were then fired, using a Bruceton sequential stair-step plan. In some few instances, when the firing of two shots at zero gap was omitted, all twenty pieces in the group were fired according to the Bruceton plan. In these cases there are no dent output values quoted.

Presentation of Results

8. The charge density, sensitivity, and output data are reported for each of the fifteen compositions at each of the five consolidating pressures in Appendix D. The average density and the standard deviation of an individual density reading are reported in units of grams/cc. The average density is also reported as percent of theoretical maximum density (TMD). The TMD for each of the fifteen mixes was computed assuming a simple additive mixture of RDX (TMD = 1.81 grams/cc) and calcium stearate (TMD = 1.04 grams/cc) according to the reported chemical analysis. The sensitivity is reported in units of DBg (the gap Decibang) which is a normalizing

transformation of the input dosage. It can be thought of as being proportional to the relative shock strength applied to the explosive in the acceptor.* The sensitivity parameters given are: AVG level, the level at which 50% response would be expected; σ, the standard deviation of an individual observation; and s_m, the standard deviation of the AVG level.

9. In order to convey an idea of the accuracy of, and the effort involved in, this calibration the following facts are presented:

a. Fifteen hundred Small Scale Gap Test shots were fired plus over a hundred more shots to check the output quality of donors and detonators.

b. Each charge holder inside diameter, and each explosive column length were measured to about 0.05% accuracy.

c. Charge weights were obtained by weighing the bodies before and after loading. Every determination was based on two independent observations which were not accepted unless they agreed within 1 milligram. (The charge weight is in the order of 1.2 to 1.5 grams and body weight 150 to 160 grams).

d. The standard deviation of charge weight and of density for any twenty bodies representing a particular combination of density and composition did not exceed 0.2% and were usually about 0.05 to 0.1%.

e. The accuracy of dent measurement is about 0.5 mils

---

* When the shock is derived from the standard SSGT donor (1) through a thickness of Lucite attenuator the DBg is computed as

$$\text{Input (DBg)} = 10 \log. \frac{\text{Reference Thickness}}{\text{Attenuator Thickness}}$$

The reference thickness being 1.0 inch and the attenuator thickness being reported in mils, the expression reduces to

$$\text{Input} = 30 - 10 \log \text{(attenuator thickness)}$$

Effect of Composition on Sensitivity and Output

10. Figures 1 through 6 have been prepared to show the effect of composition on the sensitivity of the explosive mixtures. With the consolidating pressure held constant, the mixtures become less sensitive with increasing calcium stearate content. Furthermore, the rate of desensitization is greatest at the lowest percentages and decreases as the additive is increased.

11. A curious trend can be seen in the region of the 2.54, 3.34, 4.79 and 6.07% calcium stearate mixes. The sensitivities of the 4.99% mix seem to be low compared with the 3.34 and 6.07% mixes. It is unlikely that such a trend could arise from sampling error.

12. One source of this anomaly could be faulty chemical analysis, which would shift, horizontally, all five sensitivity points for a given composition. Accordingly, two mixes were re-analyzed with the following results:

	Percent Calcium Stearate			
	Analysis by Vendor		Re-Analysis (by NOL)	
X Number	Replicates	Average	Replicates	Average
358	4.86 5.03 5.07	4.99	4.92 4.95	4.94
362	6.07 6.04 6.11	6.07	6.61 6.52	6.57

An inspection of the sensitivity curves (Figures 1 through 6) shows that replotting with the 4.94 and 6.57% data coordinates would permit redrawing the curves in a way which would give somewhat better agreement with the observed data.

13. If there were a gross error in the composition of either of these two mixes (or for any of them, for that matter) it was reasoned that this would give rise to a discrepancy in the output of the explosive as observed on the SSGT witness block with no attenuation between the donor and the acceptor. To check this concept the following scheme was used:

a. It has been found (references 1 and 2) for a fixed geometry of highly confined explosive such as in the SSGT, that the steel dent output reading is linearly related to the detonation velocity and the detonation velocity is in turn linear with the density. Since the acceptor column length and volume are the same for all tests, it seems reasonable to assume that the dent should be proportional to the amount of RDX in the acceptor.

b. The amount of RDX can be computed as the product of the volume of the acceptor, the charge density, and the proportional RDX content.

c. Since the volume is constant the variable factor will be the product of the density and the proportional RDX content, in equation form

$$P = \frac{(\%\ \mathrm{RDX})\ (\rho)}{100}$$ where P is the partial density of RDX

and ρ is the charge density.

d. The output was plotted against the partial density of RDX (Figure 7). A straight line fit of these data was made using the least squares technique.

This procedure yielded an equation relating the dent and the partial density of RDX (and thus the density and composition of the mix).

$$D = 33.76\ P + 9.29$$

where D is the dent in mils.

14. The usual statistical procedures were used to test how well the data were described by the above equation. The tests were used for all of the data points and also for each of the data groups for the fifteen mixtures. In all cases a high degree of correlation was found, with the least satisfactory fit being for the 0.59% calcium stearate mix. In particular it

should be noted that the 4.99 and 6.07% calcium stearate mix data points straddle the line. If the calcium stearate content of these mixes were assumed to be off by about 2% from the stated values (as high as 7.0 and 8.0 respectively or as low as 3.0 and 4.0), the plotted dent values would then no longer be found to straddle the regression line. This is certainly no substitute for an accurate chemical analysis to determine a chemical composition. It is however a check on the consistency of the observed behavior.

15. It does not seem that the irregularities in the sensitivity composition curves can be explained as being due solely to errors in estimation of composition. Further experimental work would be required to attempt to improve the curves. However, there are no immediate plans to pursue this effort. The explosives can be used satisfactorily for VARICOMP testing with the existing information. Perhaps somewhat less precision and sophistication can be obtained than might otherwise have been possible with smooth composition-sensitivity functions.

Effect of Consolidating Pressure on Sensitivity

16. The more generally useful relationships are those which show, for specific compositions, the effect of consolidating pressure or density upon sensitivity. These have been presented graphically in Figures D-1 through D-15 of Appendix D. Each datum point has a vertical line drawn through it, the length of which represents the expected error limits of the location of the fifty-percent firing level.

17. The minima, which are seen in the majority of the sensitivity-versus consolidating-pressure curves at about 8K psi, are not new phenomena. They represent the resultant of two competing mechanisms.

a. In general explosives become less sensitive to shock with increasing density and would therefore be expected to increase in sensitivity at the lower consolidating pressures.

b. As the explosive becomes less dense and the RDX particles in less intimate contact it is necessary that the detonation be stronger in order to bridge the increasing gap between particles.

18. A deeper insight into the system can be obtained by studying such things as the relationships between consolidating pressure, charge composition, and density (Figure 8), and also the rather novel graphic presentations of Figures 9 and 10. Calcium stearate acts as a diluent, a lubricant, and a binder. The dilution gives rise to the two effects already discussed--desensitization and reduction of output. The lubricating effect

can be seen in Figure 8. For loading pressures of 4 or 8K psi the higher the proportion of calcium stearate the nearer to the theoretical maximum density (TMD) are the charge densities. At the higher consolidating pressures it can be seen that the relative densities are maximized at intermediate calcium stearate proportions rather than at the higher levels. This also arises from the lubricating effect of the calcium stearate as evidenced by the greater spring-back which occurred. Spring-back is the term used to describe the expansion which is usually observed with pressed charges after the consolidating pressure is removed. The spring-back effect is limited in part by the friction between the acceptor walls and the explosive in contact with the walls. At the higher pressures the spring-back forces are large enough to overcome, at least partially, the wall friction forces.

Iso-Sensitivity Presentation

19. Figures 9 and 10 have been prepared in a manner analogous to the drawing of isobars and isotherms on weather maps. In Figure 9, the vertical coordinate is the consolidating pressure and the horizontal is the composition (plotted logarithmically) since these are the controllable variables. Smooth curves have then been drawn which represent the estimated loci for all the possible combinations of compositions and pressures which would be expected to have the indicated sensitivity. For the portions of the isosensitivity curves which are oriented more or less vertically the consolidating pressure has little effect on the sensitivity. Similarly when they are oriented more or less horizontally, then the dilution of the RDX by calcium stearate has relatively little effect on sensitivity.

20. For Figure 10 the vertical coordinate is the charge density rather than the consolidating pressure. Here, loci have been drawn for the 4, 8, 16, 32, and 63K psi consolidating pressures as well as for the isosensitivity points. In this presentation it can be seen that there are portions of the diagram where the isosensitivity curves are much closer together than elsewhere. In such portions, a relatively small error in composition or shift in density can bring about a considerable alteration in sensitivity. Since nearly any desired sensitivity can be achieved by a number of different combinations of the variable parameters, it seems sensible to select the composition and pressure so that the error in sensitivity will be minimized. Such a place would be where the isosensitivity lines are most widely separated.

Recommendations

21. This series of RDX/calcium-stearate mixtures is being used in the assessment of detonator-to-lead and lead-to-booster detonation transfer probabilities of a number of weapon explosive trains using the VARICOMP experimental approach. An ideal calibration of a VARICOMP explosive series would involve a smoothing of sensitivity data on the basis of chemical

composition to compensate for the variability introduced by the sampling error that is inevitable with the small sample size (18 or 20 shots per test) in the GO/NO-GO testing. In the present instance such smoothing would not be justified without further analytical and experimental investigation. Consequently, as a practical method of utilizing the explosives and their calibration data at the present state of knowledge, the following procedures are suggested for use.

a. Accept the reported values of sensitivity at each of the consolidating pressures as they are given in Appendix D.

b. To fabricate charges of a desired sensitivity select a combination of composition and pressure for which the least shift in sensitivity might arise due to an unfortunate choice. For instance, choose a combination for which the pressure is closest to a calibration pressure. Or choose a combination where there is a minimum change in sensitivity between the calibration pressure lying on each side of the chosen pressure.

c. If the explosive transfer system being tested shows an indication of being marginal so that a small error in the calibration might have serious consequences, verify the sensitivity of the combination by an SSGT calibration.

d. Assume that, for any other configuration than the SSGT acceptor, the various composition-pressure-sensitivity relations hold in the same relative manner.

22. The immediately preceeding statement is made to emphasize the fact that the sensitivity of an explosive charge is strongly affected by its configuration. For instance, had the explosives been loaded into aluminum or plastic charge holders instead of brass the explosives would have shown a decreased sensitivity. Desensitization would also have been observed had the acceptor charge diameter been much smaller or much larger than the donor diameter.

Conclusions

23. Mechanically, the RDX/calcium-stearate system is less than ideal. When pressed into cups or cylindrical cavities it handles well except at high densities and pressures where excessive spring-back is encountered. The

spring-back can be controlled to some degree by using a dwell time of five or ten seconds on each increment, with the increment length being no greater than the charge diameter. Free pellets of the explosives, such as 1/2-inch diameter by 1/2-inch long, are fragile at best. At the higher concentrations of calcium stearate the pellet is apt to break up into a series of discs. At the very low concentrations the pellet will simply crumble into a heap of lumpy powder. However, by proper choice of composition and pressure it is possible to make pellets throughout the greater region of the sensitivity spectrum covered in the calibration testing.

24. With all of the aforementioned limitations this system of explosive mixtures is proving out in the VARICOMP method of assessing detonation transfer probabilities, as a powerful experimental tool.

25. Some binary mixtures in which both components are high explosives should be a considerable improvement over the RDX/calcium stearate mixtures. These explosives should be chosen, so that in the pure form one would be comparatively sensitive and the other insensitive. On the assumption that the sensitivity of a mixture would be predictable from the ratio of their relative quantities, it would be expected that an error in composition would have less of an effect on the sensitivity than is now the case for the RDX/calcium stearate system. With both components active there should be much less degradation of performance at the insensitive end, making it much easier to establish a criterion of fire. It should also be possible to select the explosives with some consideration of density, melting point, and other physical properties so that a better physical mixture could be obtained.

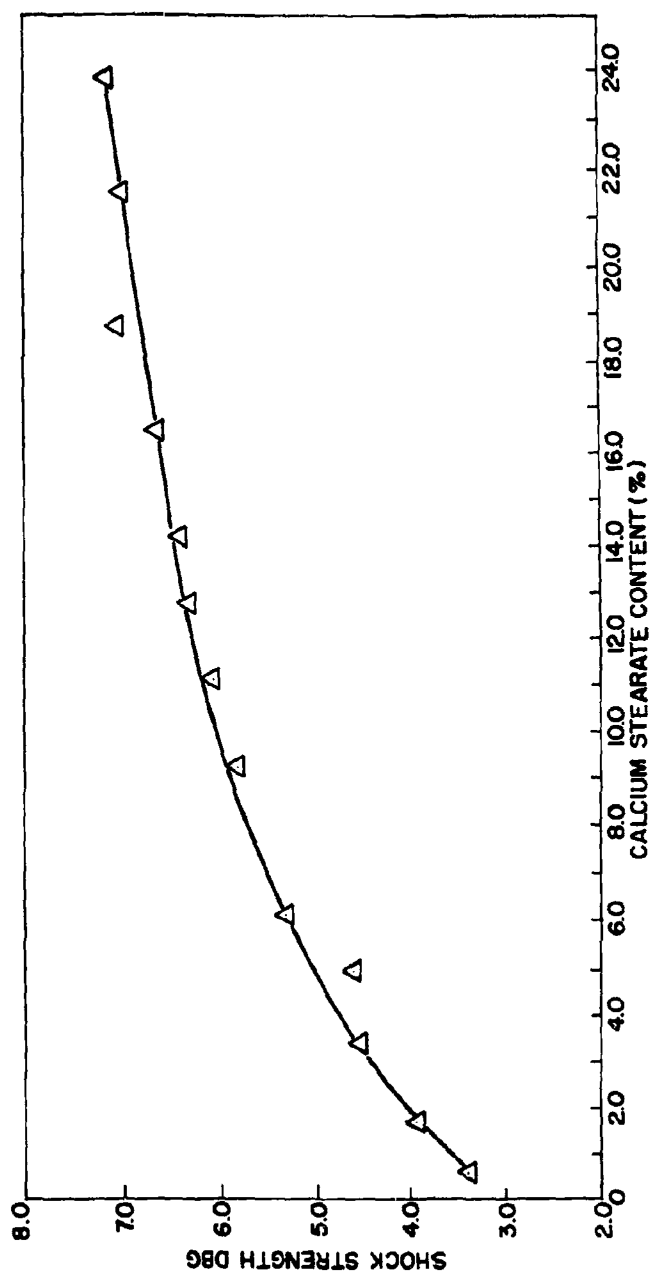

FIG. I THE EFFECT OF COMPOSITION ON THE 50% FIRING POINT OF RDX/CALCIUM STEARATE MIXTURES LOADED AT 4 KPSI.

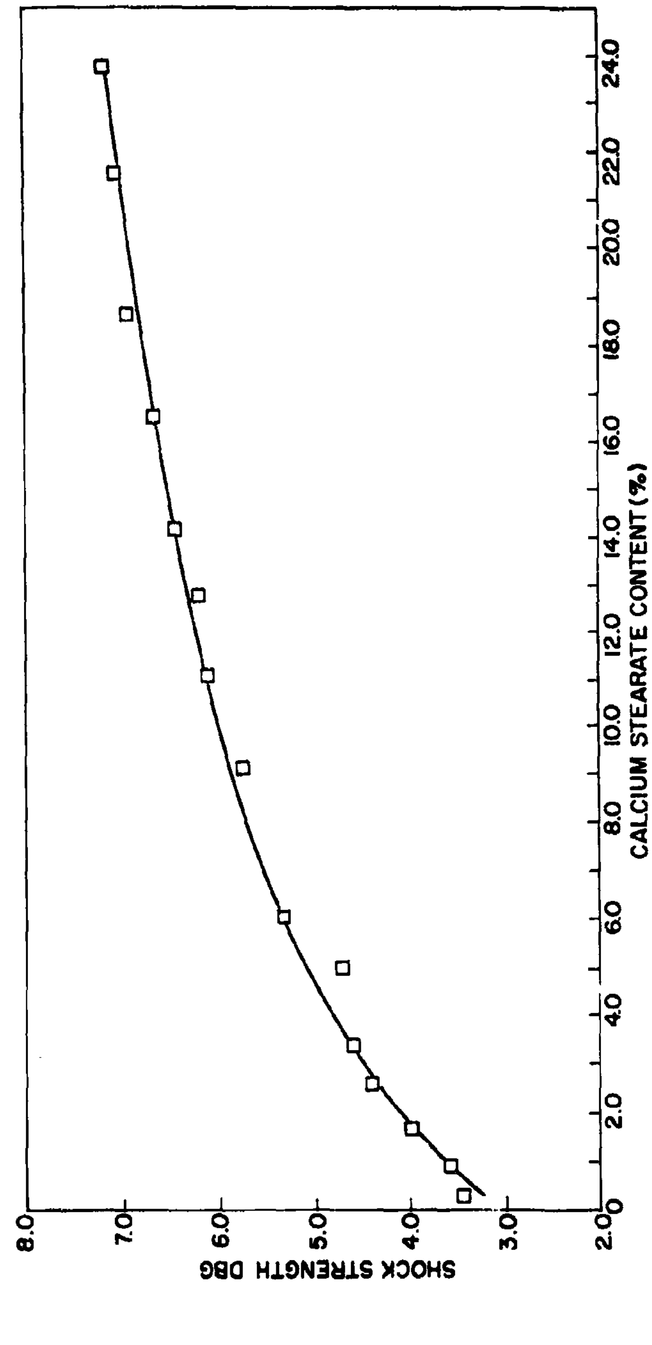

FIG. 2 THE EFFECT OF COMPOSITION ON THE 50 % FIRING POINT OF RDX/CALCIUM STEARATE MIXTURES LOADED AT 8 KPSI.

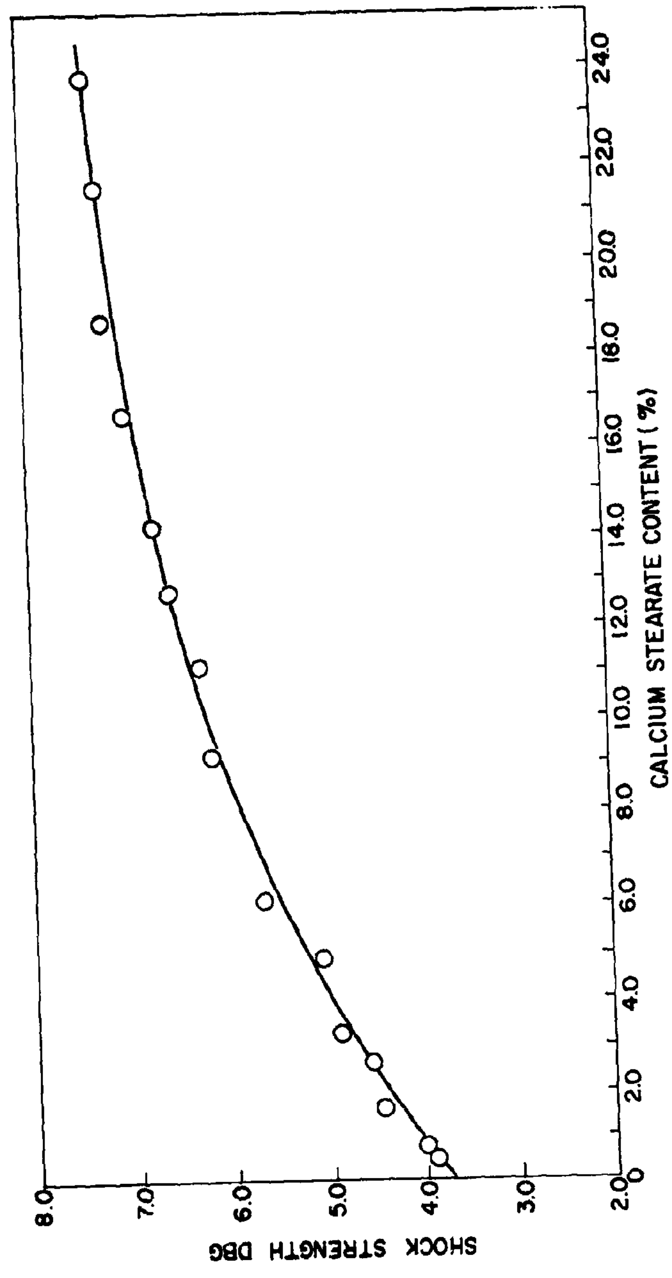

FIG. 3 THE EFFECT OF COMPOSITION ON THE 50% FIRING POINT OF RDX/CALCIUM STEARATE MIXTURES LOADED AT 16 KPSI.

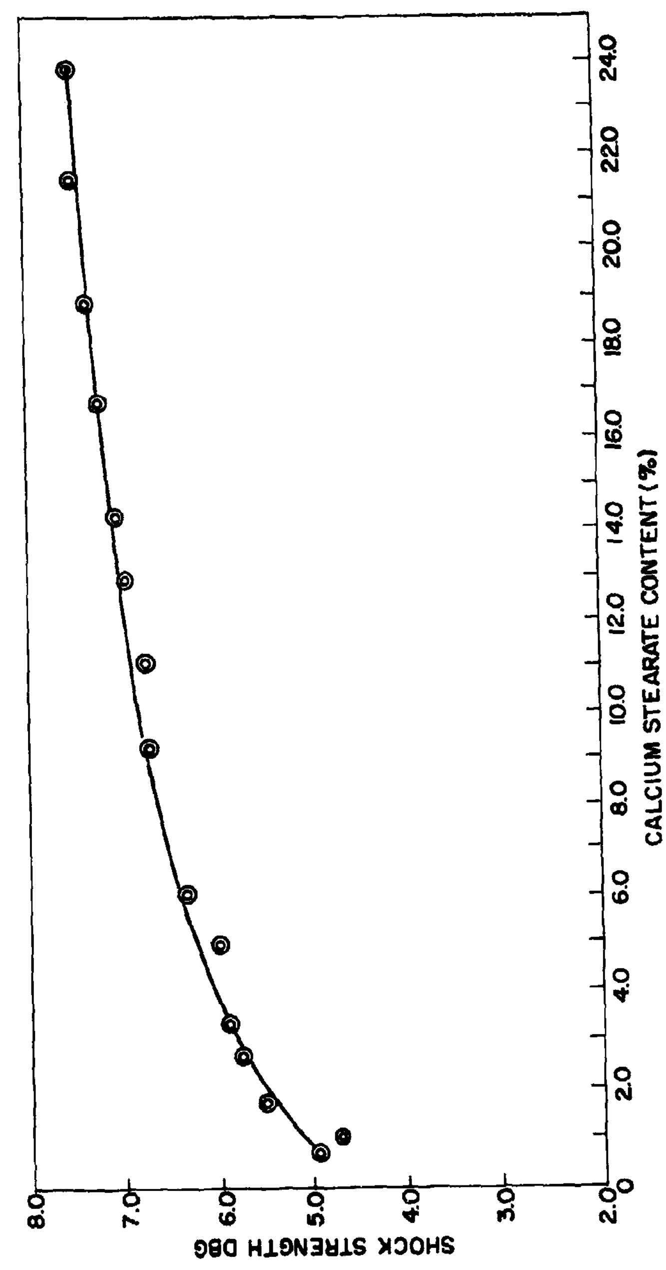

FIG. 4 THE EFFECT OF COMPOSITION ON THE 50 % FIRING POINT OF RDX/CALCIUM STEARATE MIXTURES LOADED AT 32 KPSI.

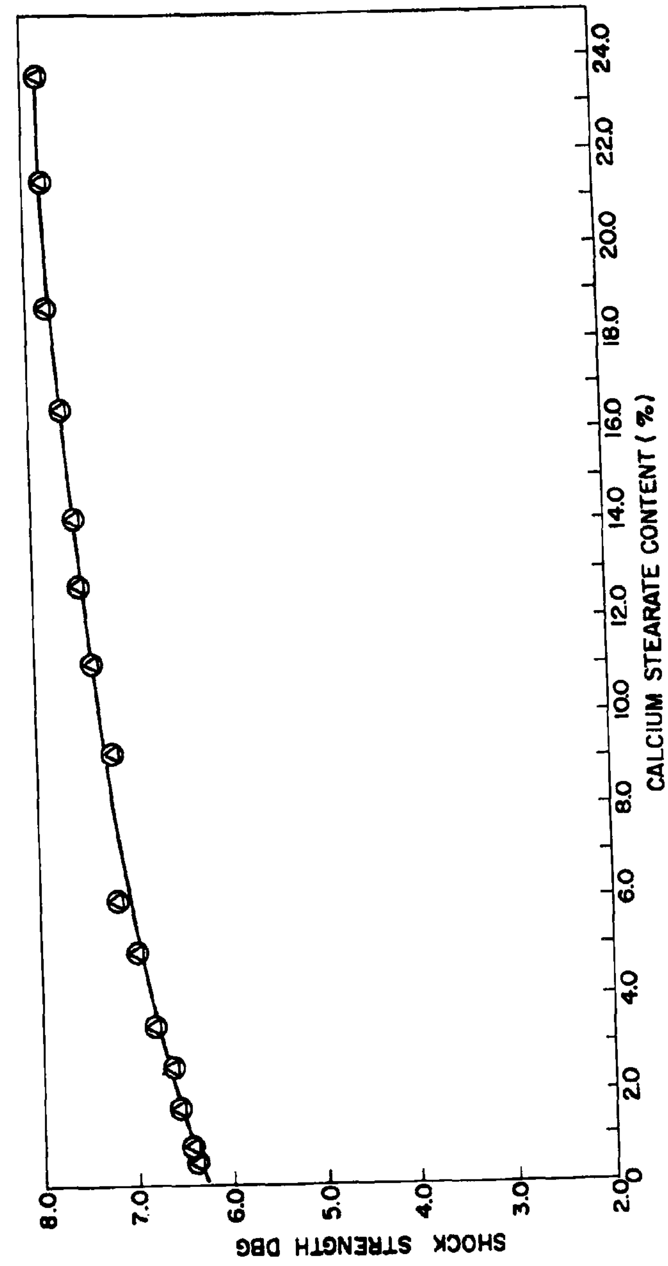

FIG. 5 THE EFFECT OF COMPOSITION ON THE 50% FIRING POINT OF RDX/CALCIUM STEARATE MIXTURES LOADED AT 64 KPSI.

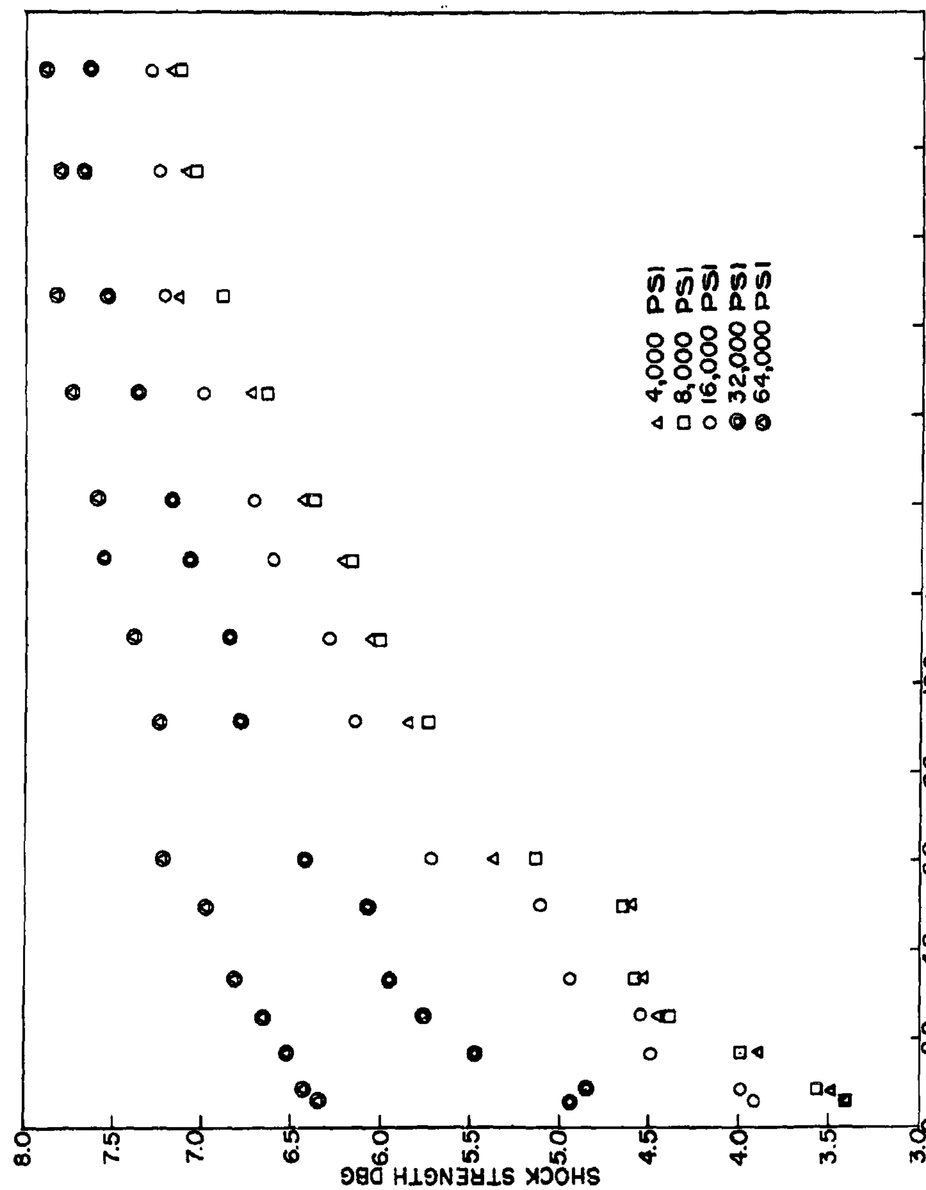

FIG. 6 THE EFFECT OF COMPOSITION AND CONSOLIDATING PRESSURE ON THE 50% FIRING POINT OF RDX/CALCIUM STEARATE MIXTURES.

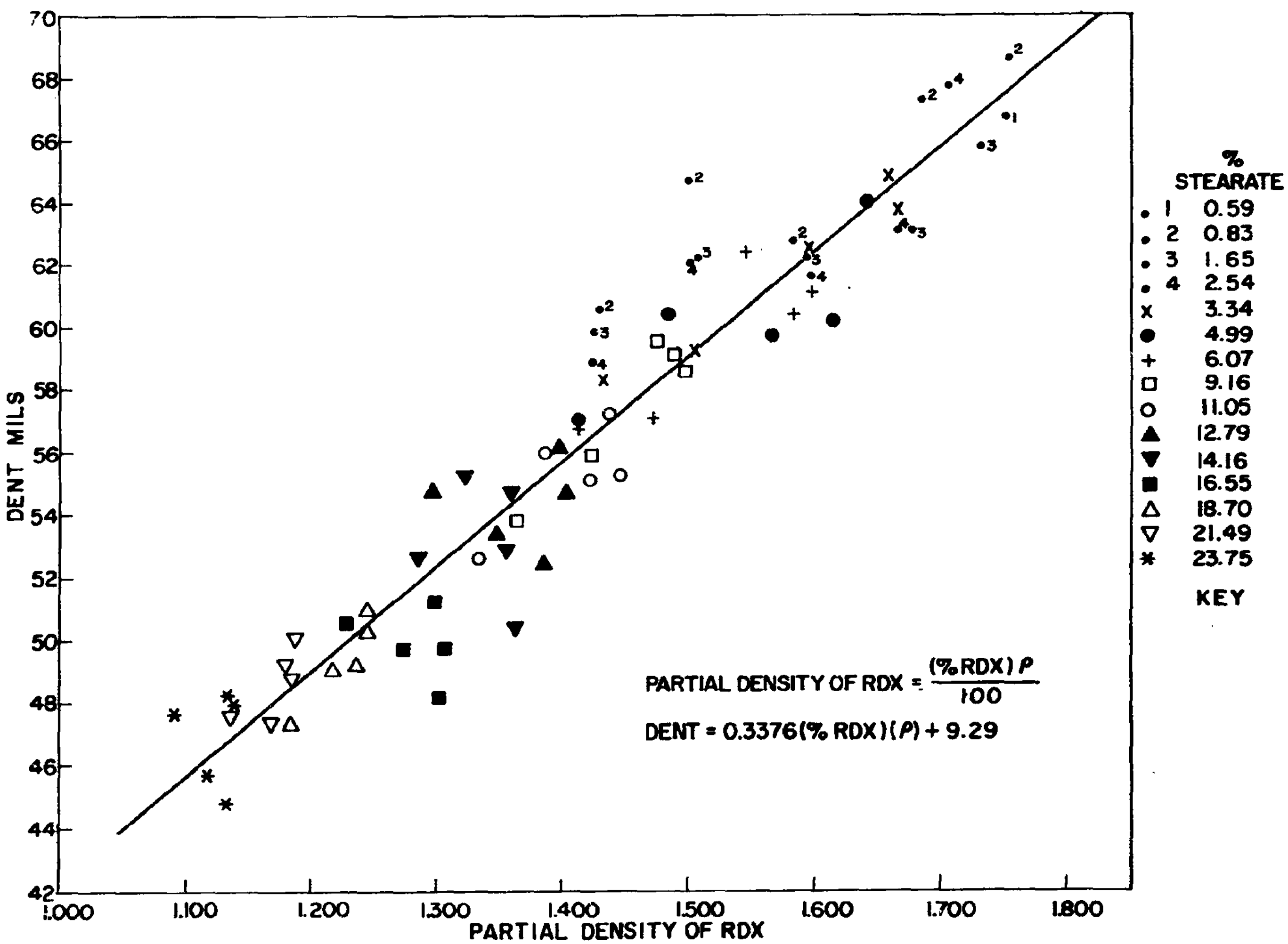

FIG. 7 CORRELATION BETWEEN RDX-CONTENT AND OUTPUT OF RDX/CALCIUM STEARATE MIXES

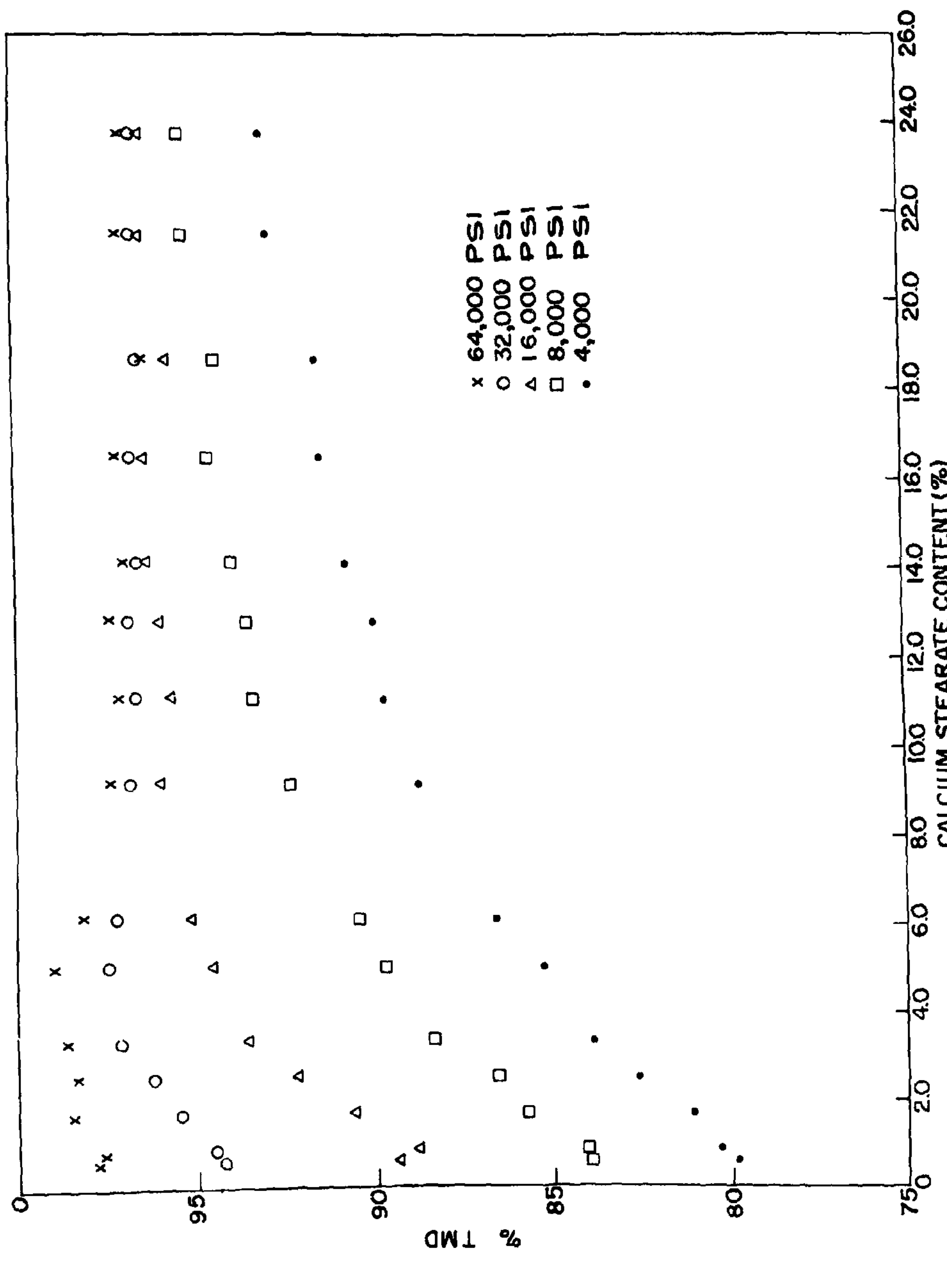

FIG. 8 THE INTERRELATIONSHIP BETWEEN CONSOLIDATING PRESSURE, COMPOSITION AND DENSITY OF RDX/CALCIUM STEARATE MIXTURES.

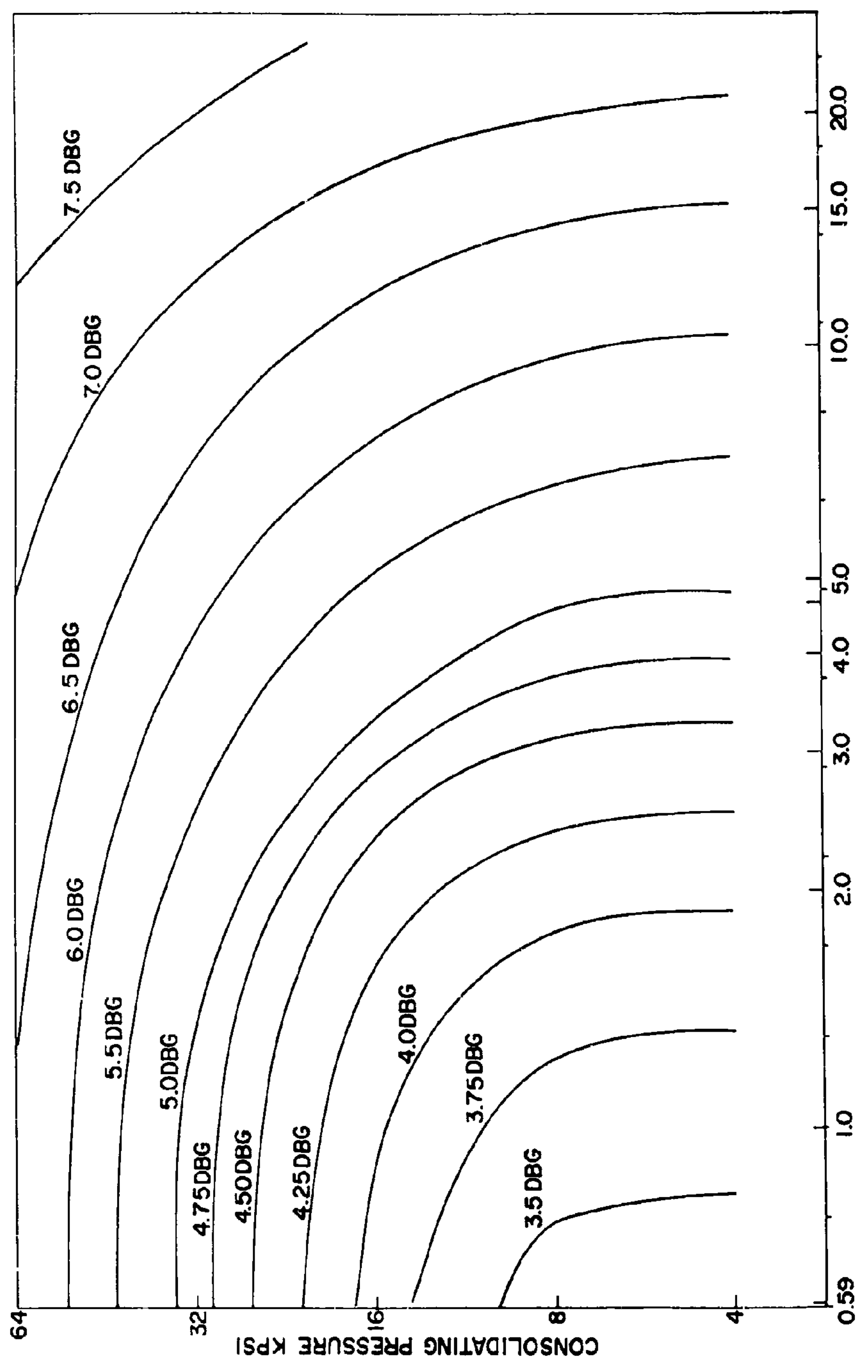

FIG. 9 CONTOUR PLOT OF THE EFFECT OF CONSOLIDATING PRESSURE AND COMPOSITION ON THE SENSITIVITY OF RDX/CALCIUM STEARATE MIXTURES.

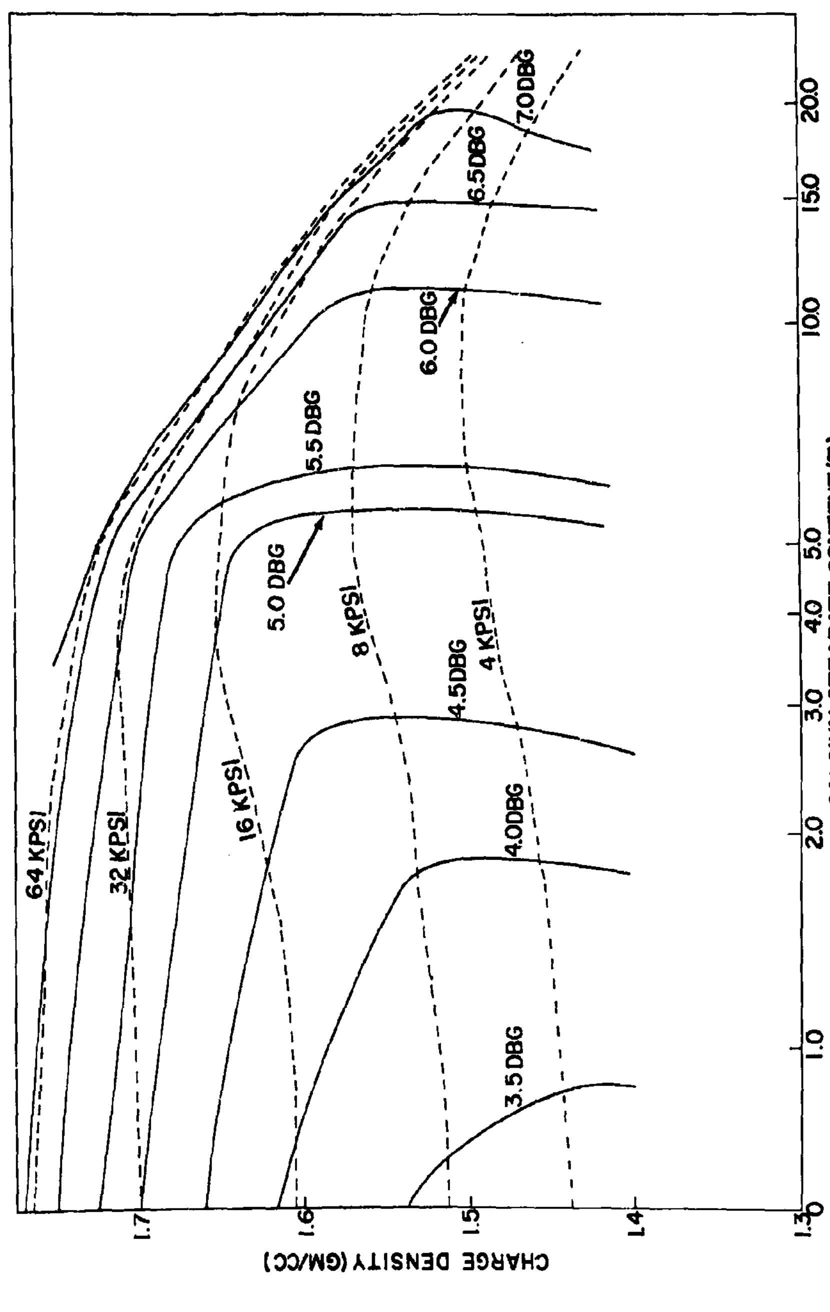

FIG. 10 THE CONSOLIDATING PRESSURE, SENSITIVITY AND DENSITY OF VARIOUS RDX/CALCIUM STEARATE COMPOSITIONS.

APPENDIX A

PROCEDURE FOR PREPARING A 100-POUND BATCH OF DESENSITIZED RDX

<u>A.1</u> Let X be the numerical value of the desired percentage of RDX in the final product.

<u>A.2</u> Prepare an RDX-water slurry by adding X pounds of RDX (JAN-R-398 Type B, Class A) to 10X pounds of distilled water at 70 to 80° Centigrade.

<u>A.3</u> Prepare a sodium stearate solution by dissolving (100-X) pounds of sodium stearate (Technical Grade) in (1300-13X) pounds of distilled water at 70-80° Centigrade.

<u>A.4</u> Prepare a calcium chloride solution by dissolving (75-0.75X) pounds of calcium chloride (O-C-104, Class 1) in (1500-15X) pounds of distilled water at 70-80° Centigrade.

<u>A.5</u> Add the sodium stearate solution to the RDX slurry with rapid stirring.

<u>A.6</u> With rapid stirring, add the calcium chloride to the RDX-sodium stearate mixture (addition should take from 15 to 30 minutes).

<u>A.7</u> Filter and wash with distilled water until the effluent wash water is free of chloride ion. This can be detected by testing the wash water with a silver nitrate solution.

<u>A.8</u> Dry the filtered and washed product at 70° Centigrade on trays over steam coils.

APPENDIX B

ANALYTIC PROCEDURE FOR RDX/CALCIUM STEARATE MIXES

B. 1 Procedure

B. 1. 1 Sample size should be set to yield approximately 0.3 gram of calcium stearate after the extraction of the RDX. From the standpoint of safety an upper limit of 3- to 5- gram sample size is recommended.

B. 1. 2 Standard dry powder sampling and sample blending procedures should be employed.

B. 1. 3 Medium porosity sintered glass crucible should be thoroughly washed, soaked in boiling acetone, dried and tared.

B. 1. 4 Sample should be weighed in the tared sintered glass crucible.

B. 1. 5 The weight loss by volatiles should be determined by weighing the sample and crucible after vacuum drying for one hour at 70° Centigrade and 50-millimeters Hg absolute pressure.

B. 1. 6 The RDX should be extracted by 8 washings of 20 milliliters each of boiling acetone. During each washing the sample should be triturated continuously with a tared glass stirring rod, in order to break all lumps.

B. 1. 7 The calcium stearate residue, crucible, and stirring rod should be vacuum dried for one hour at 70° Centigrade and 50-millimeters Hg. absolute pressure.

B. 1. 8 The residue and glassware should be weighed after being allowed to cool for 30 minutes in a desiccator. The weight loss from the acetone extraction is taken as the amount of RDX and the weight of the residue as calcium stearate.

B. 2 Precautionary Notes

B. 2. 1 Particularly above about 8 percent of calcium stearate the analysis becomes rather difficult and subject to gross error due to poor analytic technique. The error seems to be due to incomplete RDX extraction which apparently is due to the tendency of the calcium stearate to form a protective coating on the surface of the RDX particles. The obvious approach of increasing the amount of washing with hot acetone is not considered advisable because of the increased chance of loss of calcium stearate.

B. 2. 2 Particularly when there seems to be an unacceptably high volatile content, (above 0.2 percent should be viewed with suspicion) there may have not been adequate washing of the mix during its manufacture. In such cases the presence of calcium chloride should be suspected since such a material would lead to hygroscopicity of the mix.

B. 2. 3 At the present time a specific procedure has not been developed for the quantitative determination of the chloride ion. A number of approaches seem promising. Perhaps the best one is to perform a replicate analysis as above except for the inclusion of an extra step between steps B. 1. 5 and B. 1. 6 which would include a water wash followed by a vacuum drying and reweighing of the residue and a quantitative precipitation of chloride ion from the filtrate.

APPENDIX C

Manufacturer's Identification	NOL X Number	Percent Calcium Stearate Manufacturer's Analytic Data: Average	Observed Error	SSGT Data Location
1	348	0.59	0.05	D-1
2	349	0.83	0.15	D-2
3	350	1.65	0.06	D-3
4	351	----	----	---
5	352	----	----	---
Blend 4, 5	353	2.54	0.03	D-4
Blend 6, 7	354	3.34	0.14	D-5
8	355	4.73	----	---
9	356	----	----	---
10	357	4.56	----	---
Blend 8, 9, 10	358	4.99	0.28	D-6
11	359	7.03	----	---
12	360	5.91	----	---
13	361	7.08	----	---
Blend 11, 12, 13	362	6.07	0.09	D-7
14	363	10.43	----	---

APPENDIX C (continued)

Manufacturer's Identification	NOL X Number	Percent Calcium Stearate Manufacturer's Analytic Data: Average	Observed Error	SSGT Data Location
15	364	9.69	----	---
16	365	10.02	----	---
Blend 14, 15, 16	366	9.16	0.24	D-8
17	367	12.05	----	---
18	368	11.90	----	---
19	369	11.45	----	---
Blend 17, 18, 19	370	11.05	0.45	D-9
20	371	12.86	----	---
21	372	13.95	----	---
30	373	13.96	----	---
Blend 20, 21, 30	374	12.79	0.44	D-10
22	375	15.05	----	---
23	376	14.84	----	---
31	377	15.94		
Blend 22,23,31	378	14.16	0.11	D-11

APPENDIX C (continued)

Manufacturer's Identification	NOL X Number	Percent Calcium Stearate Manufacturer's Analytic Data: Average	Observed Error	SSGT Data Location
24	379	17.50	----	---
25	380	17.65	----	---
Blend 24, 25	381	16.55	0.31	D-12
26	382	20.74	----	---
27	383	19.79	----	---
Blend 26, 27	384	18.70	0.42	D-13
28	385	21.49	0.47	D-14
29	386	23.75	0.37	D-15

APPENDIX D

COMPOSITION: 0.59% CALCIUM STEARATE
SPECIFIED 0.7; DELIVERED 0.59;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	DENSITY (GRAMS/CC) δ	% TMD	SHOCK STRENGTH, DBG AVG	SHOCK STRENGTH, DBG δ	SHOCK STRENGTH, DBG δM	OUTPUT DENT (MILS)
4	1.4392	0.0070	79.866	3.412	0.2402	0.080 *	
8	1.5133	0.0062	83.978	3.424	0.2057	0.068 *	
16	1.6111	0.0059	89.406	3.910	0.0850	0.030	
32	1.6986	0.0050	94.261	4.938	0.138	0.055	58.2
64	1.7629	0.0084	97.830	6.375	0.137	0.046	66.7

* δ M ESTIMATED

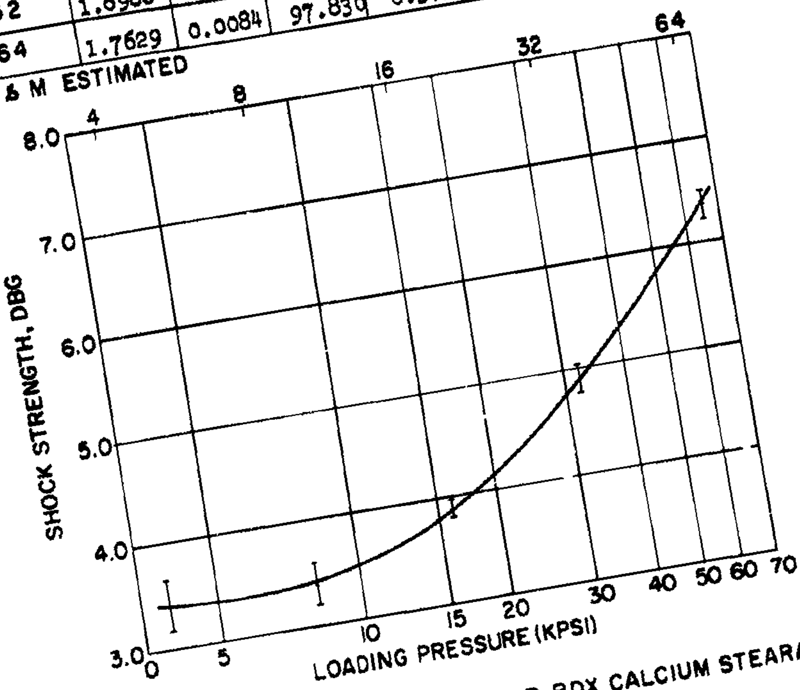

FIG. D-1 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X— NO. 348.

APPENDIX D

COMPOSITION:

0.83% CALCIUM STEARATE

SPECIFIED 1.0; DELIVERED 0.83;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	σ	% TMD	SHOCK STRENGTH, DBG AVG	σ	σ M	OUTPUT DENT (MILS)
4	1.442	0.0022	80.277	3.484	0.054	0.018 *	60.6
8	1.5134	0.0041	84.124	3.565	0.0562	0.022	64.7
16	1.5976	0.0026	88.804	3.991	0.056	0.018 *	62.8
32	1.7006	0.0050	94.530	4.846	0.086	0.031	67.3
64	1.7673	0.0054	97.682	6.432	0.142	0.047	68.6

* σ M ESTIMATED

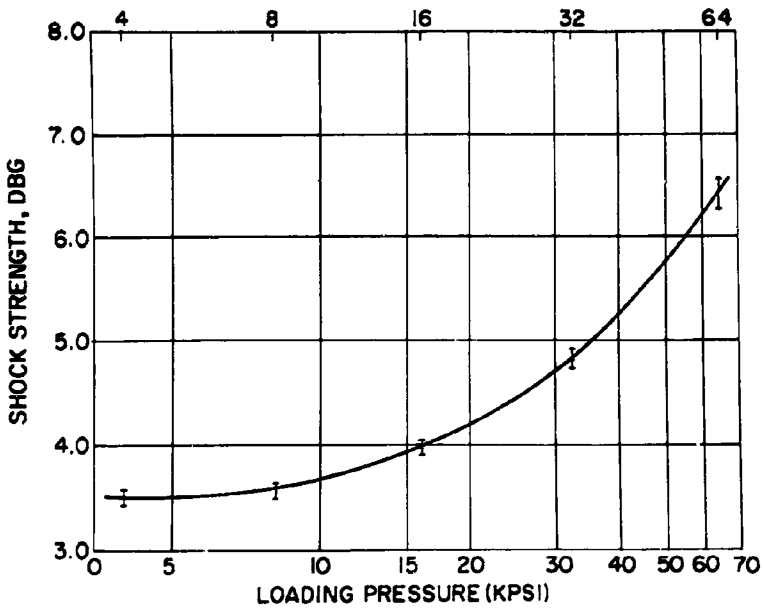

FIG.D-2 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 349.

APPENDIX D

COMPOSITION:

1.65% CALCIUM STEARATE

SPECIFIED 2.0; DELIVERED 1.65;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	DENSITY (GRAMS/CC) ∆	% TMD	SHOCK STRENGTH, DBG AVG	SHOCK STRENGTH, DBG ∆	SHOCK STRENGTH, DBG ∆M	OUTPUT DENT (MILS)
4	1.4495	0.0089	81.068	3.896	0.052	0.017 *	59.9
8	1.533	0.0099	85.738	3.964	0.135	0.046	62.2
16	1.6213	0.0093	90.676	4.479	0.143	0.049	62.2
32	1.7075	0.0053	95.497	5.469	0.045	0.015 *	63.1
64	1.7602	0.0039	98.445	6.531	0.092	0.034	65.7

* ∆ M ESTIMATED

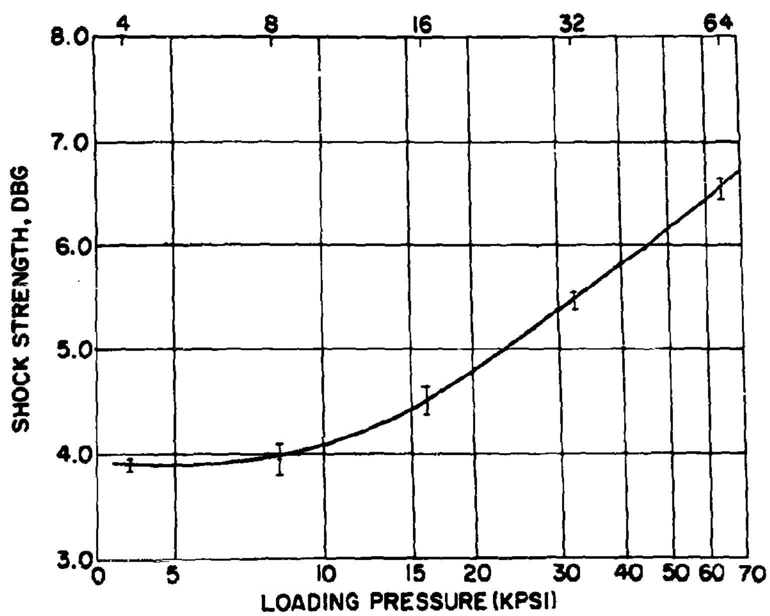

FIG. D-3 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 350.

APPENDIX D

COMPOSITION:

2.54% CALCIUM STEARATE

SPECIFIED 2.8; DELIVERED 2.54;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	DENSITY (GRAMS/CC) δ	% TMD	SHOCK STRENGTH, DBG AVG	SHOCK STRENGTH, DBG δ	SHOCK STRENGTH, DBG δ M	OUTPUT DENT (MILS)
4	1.4682	0.0079	82.622	4.462	0.089	0.032	58.8
8	1.5400	0.0087	86.662	4.389	0.094	0.033	62.1
16	1.6386	0.0105	92.211	4.547	0.077	0.029	61.6
32	1.7103	0.0054	96.246	5.757	0.057	0.019 *	63.1
64	1.7521	0.0046	98.598	6.639	0.094	0.033	67.7

* δ M ESTIMATED

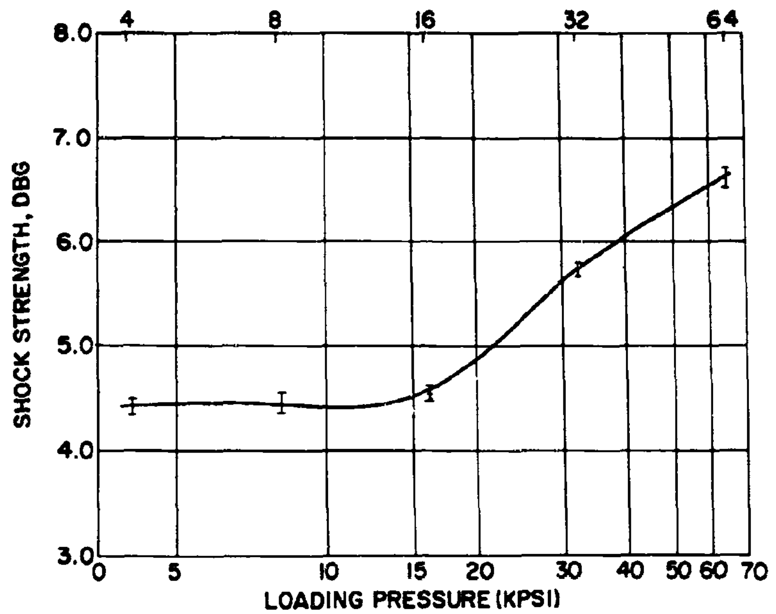

FIG. D-4 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 353.

APPENDIX D

COMPOSITION:

3.34% CALCIUM STEARATE

SPECIFIED 4.0; DELIVERED 3.34;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	DENSITY (GRAMS/CC) δ	% TMD	SHOCK STRENGTH, DBG AVG	SHOCK STRENGTH, DBG δ	SHOCK STRENGTH, DBG δ M	OUTPUT DENT (MILS)
4	1.4815	0.0045	83.842	4.540	0.012	0.042	58.3
8	1.5617	0.0106	88.381	4.551	0.073	0.027	59.2
16	1.6528	0.0038	93.537	4.940	0.056	0.023	62.5
32	1.7160	0.0020	97.113	5.951	0.027	0.009 *	64.8
64	1.7423	0.0034	98.602	6.810	0.056	0.022	63.7

* δ M ESTIMATED

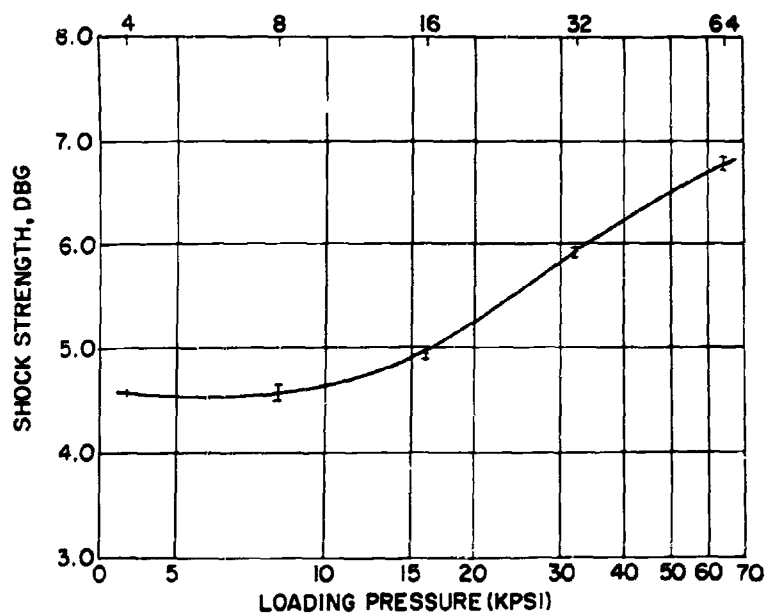

FIG. D-5 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 354.

APPENDIX D

COMPOSITION:

4.99% CALCIUM STEARATE

SPECIFIED 5.6; DELIVERED 4.99;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	σ	% TMD	SHOCK STRENGTH, DBG AVG	σ	σ M	OUTPUT DENT (MILS)
4	1.4873	0.0076	85.232	4.580	0.073	0.027	57.0
8	1.5657	0.0052	89.724	4.645	0.142	0.046	60.4
16	1.6515	0.0028	94.641	5.104	0.052	0.017 *	59.7
32	1.7008	0.0017	97.467	6.078	0.076	0.029	60.2
64	1.7274	0.0054	98.991	6.985	0.252	0.081	64.0

* σ M ESTIMATED

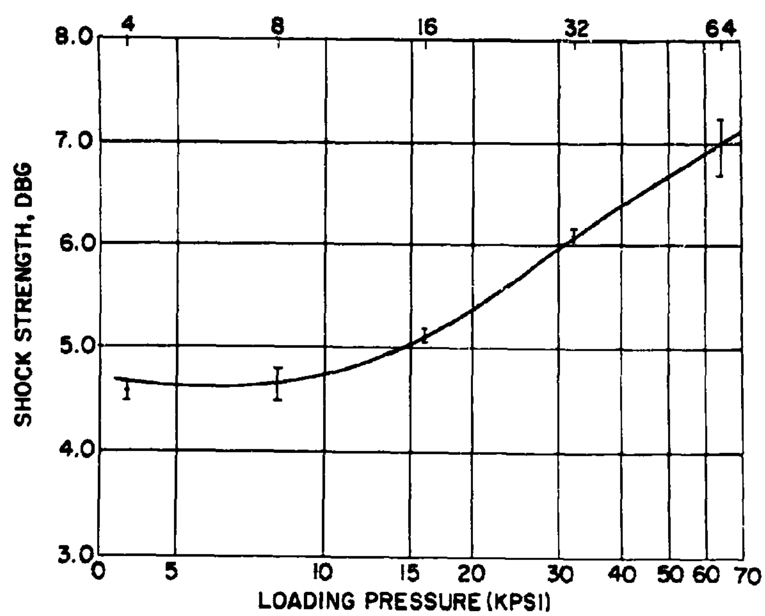

FIG. D-6 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 358.

APPENDIX D

COMPOSITION:

6.07% CALCIUM STEARATE

SPECIFIED 8.0; DELIVERED 6.07;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	σ	% TMD	SHOCK STRENGTH, DBG AVG	σ	σ M	OUTPUT DENT (MILS)
4	1.5018	0.0076	86.659	5.363	0.326	0.105	56.8
8	1.5676	0.0078	90.455	5.148	0.132	0.045	57.1
16	1.6489	0.0043	95.147	5.719	0.045	0.015 *	62.4
32	1.6853	0.0023	97.247	6.420	0.073	0.027	60.4
64	1.7012	0.0037	98.165	7.221	0.169	0.055	61.3

* σ M ESTIMATED

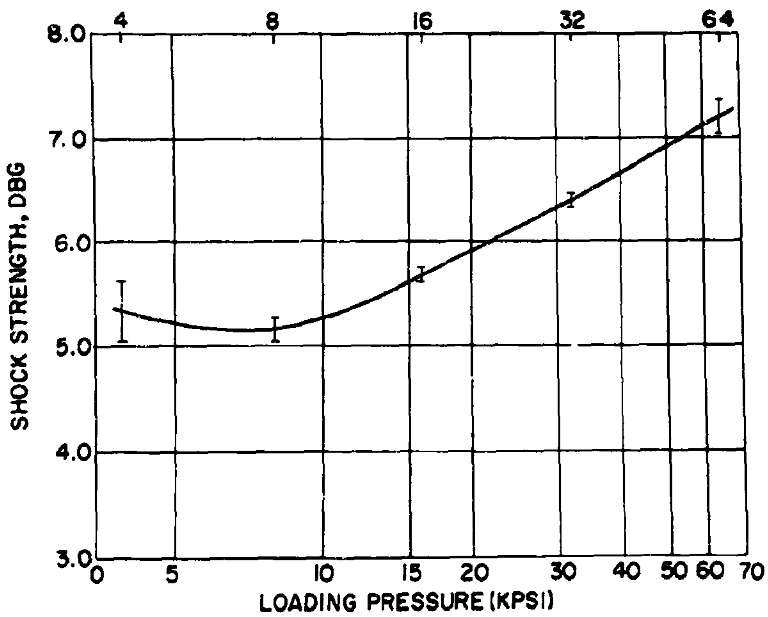

FIG. D-7 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 362.

APPENDIX D

COMPOSITION:

9.16% CALCIUM STEARATE

SPECIFIED 12.0;DELIVERED 9.16;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	δ	% TMD	SHOCK STRENGTH, DBG AVG	δ	δ M	OUTPUT DENT (MILS)
4	1.5029	0.0040	88.719	5.851	0.094	0.035	52.8
8	1.5638	0.0025	92.314	5.729	0.052	0.017 *	55.9
16	1.6254	0.0061	95.950	6.141	0.117	0.039	59.6
32	1.6393	0.0059	96.770	6.795	0.131	0.044	59.1
64	1.6497	0.0023	97.384	7.243	0.057	0.019 *	58.6

* δ M ESTIMATED

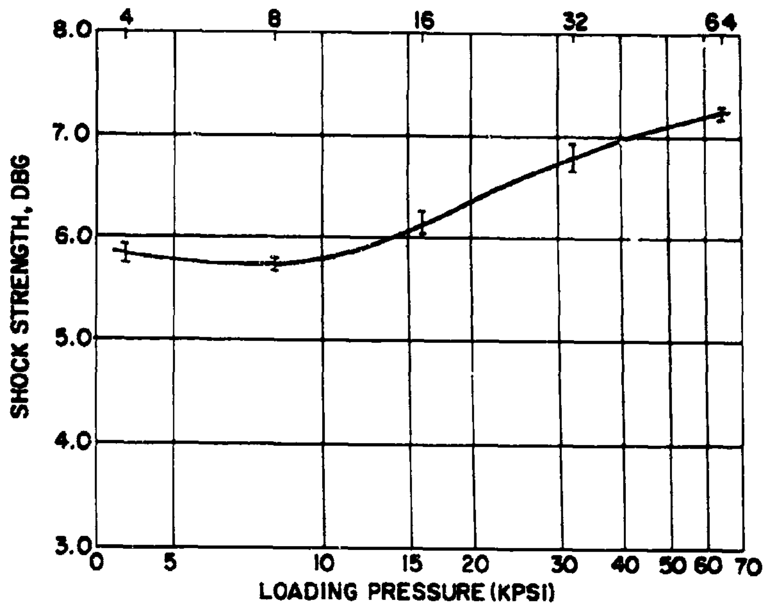

FIG. D-8 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X—NO. 366.

APPENDIX D

COMPOSITION:

11.05% CALCIUM STEARATE

SPECIFIED 14.0;DELIVERED 11.05;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	δ	% TMD	SHOCK STRENGTH, DBG AVG	δ	δ M	OUTPUT DENT (MILS)
4	1.5011	0.0057	89.725	6.080	0.073	0.027	52.6
8	1.5611	0.0027	93.311	6.016	0.054	0.018 *	56.0
16	1.6008	0.0015	95.684	6.297	0.029	0.009 *	55.1
32	1.6176	0.0018	96.688	6.851	0.100	0.035	57.2
64	1.6251	0.0028	97.136	7.396	0.052	0.017 *	55.2

* δ M ESTIMATED

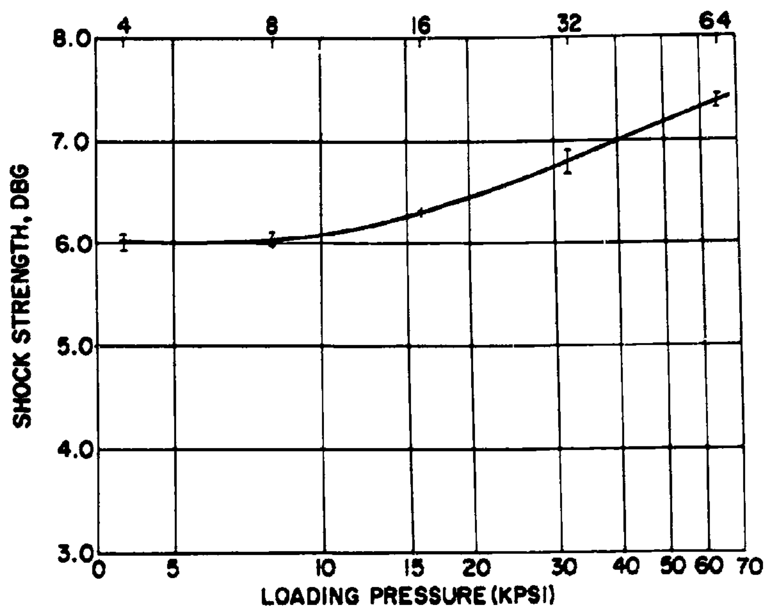

FIG. D-9 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 370.

APPENDIX D

COMPOSITION:

12.79% CALCIUM STEARATE

SPECIFIED 16.0; DELIVERED 12.79;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	ẟ	% TMD	SHOCK STRENGTH, DBG AVG	ẟ	ẟ M	OUTPUT DENT (MILS)
4	1.4875	0.0069	89.987	6.285	0.042	0.0014*	54.7
8	1.5459	0.0036	93.520	6.173	0.116	0.039	53.3
16	1.5866	0.0025	95.983	6.604	0.095	0.033	52.4
32	1.6012	0.0013	96.866	7.007	0.057	0.019 *	56.2
64	1.6089	0.0023	97.332	7.551	0.073	0.027	54.7

* ẟ M ESTIMATED

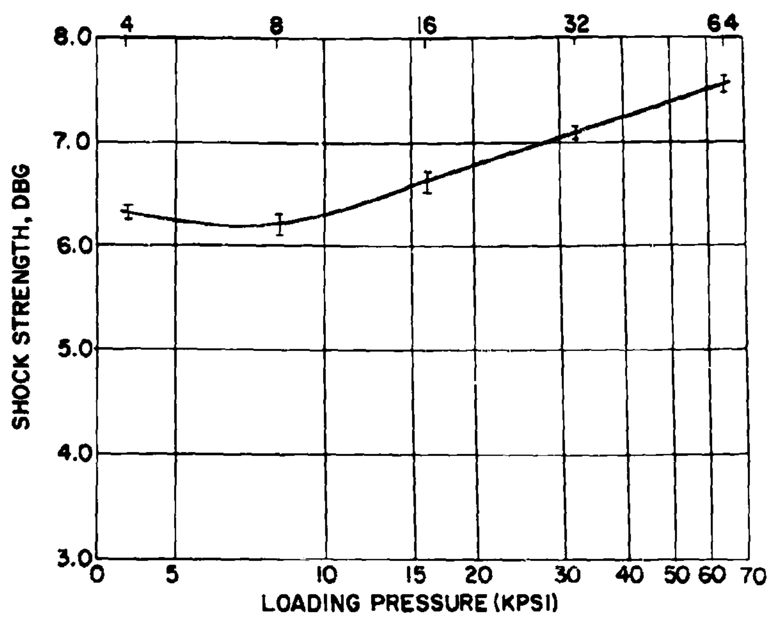

FIG. D-10 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X—NO. 374.

APPENDIX D

COMPOSITION:

14.16% CALCIUM STEARATE

SPECIFIED 18.4; DELIVERED 14.16;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	δ	% TMD	SHOCK STRENGTH, DBG AVG	δ	δ M	OUTPUT DENT (MILS)
4	1.4873	0.0041	90.744	6.435	0.056	0.022	52.6
8	1.5405	0.0023	93.990	6.375	0.057	0.019 *	55.2
16	1.5784	0.0021	96.302	6.719	0.045	0.018 *	52.8
32	1.5828	0.0034	96.571	7.174	0.027	0.009 *	54.7
64	1.5887	0.0029	96.931	7.594	0.108	0.036 *	50.3

* δ M ESTIMATED

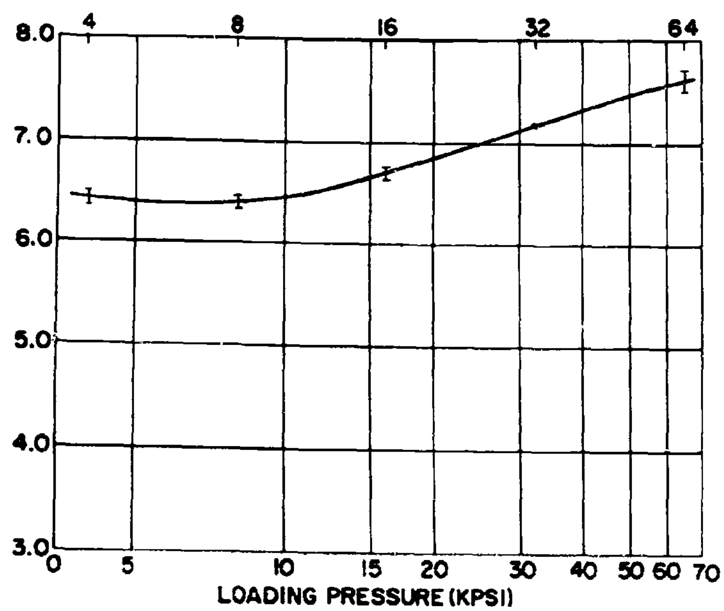

FIG. D-11 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 378.

APPENDIX D

COMPOSITION:

16.55% CALCIUM STEARATE

SPECIFIED 20.8; DELIVERED 16.55;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC)		% TMD	SHOCK STRENGTH, DBG			OUTPUT DENT (MILS)
	AVG	δ		AVG	δ	δ M	
4	1.4738	0.0031	91.426	6.726	0.100	0.035	50.5
8	1.5245	0.0025	94.571	6.646	0.052	0.017 *	49.7
16	1.5536	0.0013	96.377	6.993	0.057	0.019 *	51.2
32	1.5597	0.0014	96.755	7.368	0.057	0.019 *	48.1
64	1.5662	0.0026	97.158	7.729	0.052	0.017 *	49.7

* δ M ESTIMATED

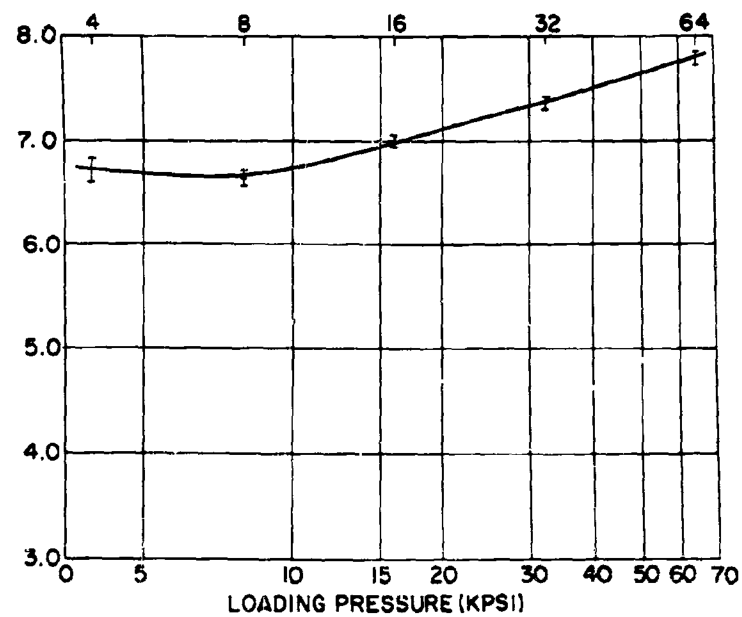

FIG. D-12 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 381.

APPENDIX D

COMPOSITION:

18.70% CALCIUM STEARATE

SPECIFIED 23.3; DELIVERED 18.70;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	DENSITY (GRAMS/CC) δ	% TMD	SHOCK STRENGTH, DBG AVG	SHOCK STRENGTH, DBG δ	SHOCK STRENGTH, DBG δ M	OUTPUT DENT (MILS)
4	1.4544	0.0042	91.529	7.126	0.104	0.037	47.3
8	1.4988	0.0035	94.323	6.894	0.172	0.057	48.9
16	1.5207	0.0020	95.701	7.212	0.089	0.032	49.1
32	1.5315	0.0023	96.381	7.535	0.085	0.030	50.2
64	1.5308	0.0038	96.337	7.818	0.142	0.047	50.7

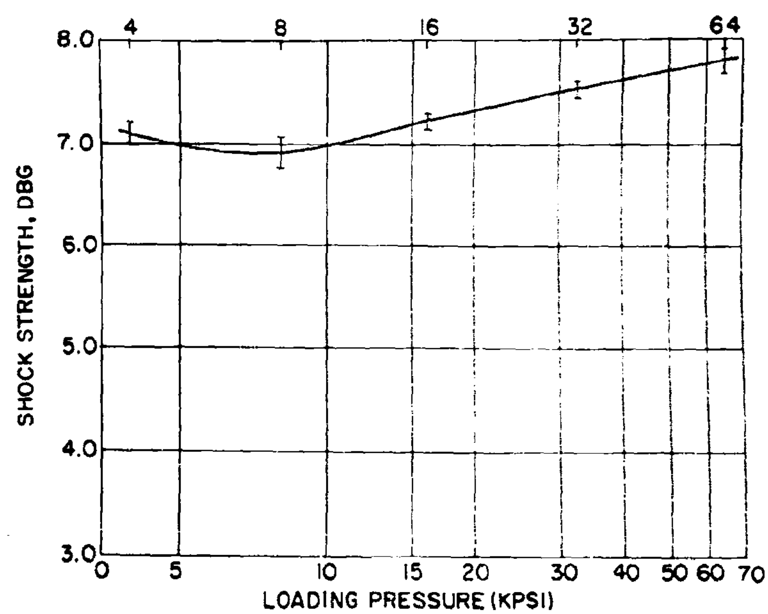

FIG.D-13 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X—NO. 384.

APPENDIX D

COMPOSITION:

21.49% CALCIUM STEARATE

SPECIFIED 26.0; DELIVERED 21.49;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	DENSITY σ	% TMD	SHOCK STRENGTH, DBG AVG	SHOCK STRENGTH, DBG σ	SHOCK STRENGTH, DBG σ M	OUTPUT DENT (MILS)
4	1.4494	0.0028	92.850	7.054	0.038	0.020	47.5
8	1.4865	0.0026	95.227	7.048	0.116	0.039	47.3
16	1.5057	0.0024	96.457	7.236	0.094	0.033	49.2
32	1.5097	0.0020	96.713	7.660	0.086	0.028 *	48.7
64	1.5150	0.0029	97.053	7.798	0.070	0.026	50.0

* σ M ESTIMATED

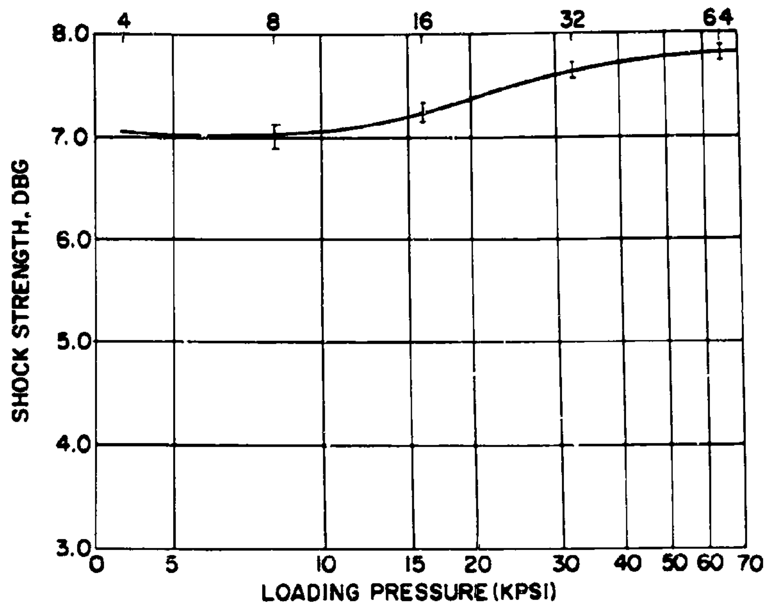

FIG. D-14 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 385.

APPENDIX D

COMPOSITION:

23.75% CALCIUM STEARATE

SPECIFIED 28.0; DELIVERED 23.75;

LOADING PRESSURE (KPSI)	DENSITY (GRAMS/CC) AVG	σ	% TMD	SHOCK STRENGTH, DBG AVG	σ	σ M	OUTPUT DENT (MILS)
4	1.4308	0.0029	92.969	7.174	0.027	0.009 *	47.5
8	1.4662	0.0020	95.269	7.132	0.057	0.019 *	45.7
16	1.4842	0.0046	96.439	7.286	0.129	0.043	44.7
32	1.4878	0.0024	96.673	7.632	0.057	0.019 *	48.2
64	1.4927	0.0026	96.991	7.882	0.057	0.019 *	47.9

* σ M ESTIMATED

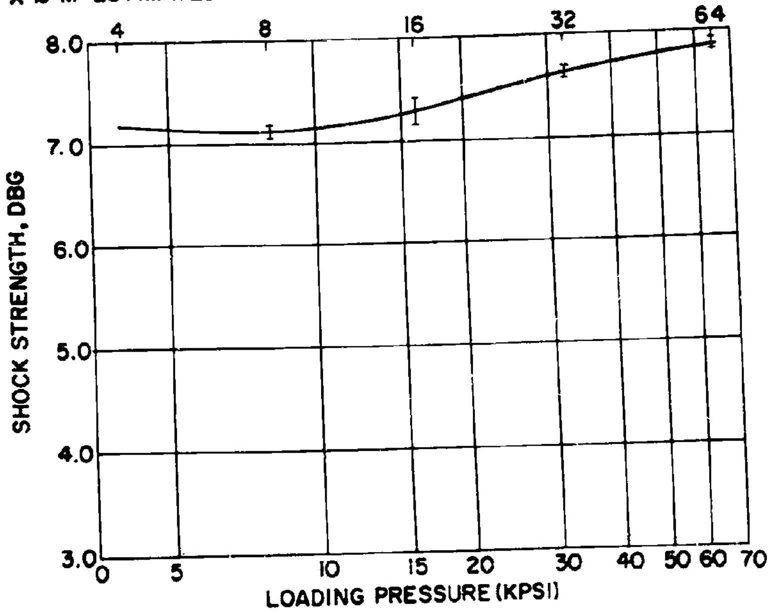

FIG. D-15 LOADING AND FIRING DATA FOR RDX CALCIUM STEARATE MIX X-NO. 386.

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General Electric Co. Missile & Ordnance Systems Department 2198 Chestnut Street Philadelphia, Pennsylvania T. W. Kennedy	1
Elgin National Watch Co. Micronics Division 21001 Nordhoff Chatsworth, California	1
Hamilton Watch Co. Allied Products Division Lancaster, Pennsylvania	1
The Martin Co. 815 Elwell Street Orlando, Florida	1
McDonnell Aircraft Corp. P. O. Box 516 St. Louis, Missouri	1
Flare-Northern Division Atlantic Research Corp. 19701 W. Goodvale Road Saugus, California	1
Daystrom Electric Corp. 229-A Manchester Road Poughkeepsie, New York	1

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	DESCRIPTORS	CODES		DESCRIPTORS	CODES
SOURCE	NOL technical report	NOLTR	SECURITY CLASSIFICATION AND CODE COUNT	Unclassified - 26	UØ26
REPORT NUMBER	63-91	63ØØ91	CIRCULATION LIMITATION		
REPORT DATE	15 May 1963	Ø563	CIRCULATION LIMITATION OR BIBLIOGRAPHIC		
			BIBLIOGRAPHIC (SUPPL., VOL., ETC.)		

SUBJECT ANALYSIS OF REPORT

DESCRIPTORS	CODES	DESCRIPTORS	CODES	DESCRIPTORS	CODES
RDX	RDXE	Density	DENS	Explosives (test)	EXPLT
Calcium	CALU	Output	OUTP	Iso	ISOA
Stearate	STAA	Small	SMAL		
Mixtures	MIXT	Scale	SCLS		
Binary	BINA	Gap test	GAPT		
System	SYST	VARICOMP	VRIC		
Explosive	EXPL	Measurement	MEAU		
Sensitivity	SENV	Weapon	WEAP		
Calibration	CALB	Explosive train	EXPO		
Composition	CMPO	Safety	SAFE		
Consolidating	CNSD	Reliability	RELI		
Pressure	PRES	Compounds	CMPU		

PRNC-NOL-5070/28 (5-62)

Naval Ordnance Laboratory, White Oak, Md.
(NOL technical report 63-91)
RDX/CALCIUM-STEARATE BINARY SYSTEM EXPLOSIVE SENSITIVITY CALIBRATION, by J. N. Ayres and C. W. Randall. 15 May 1963. 9p. illus., tables
UNCLASSIFIED

The effects of composition and consolidating pressure on density, sensitivity, and output of RDX/Calcium-Stearate mixtures have been determined using the Small Scale Gap Test. These mixtures can be used to satisfy the immediate needs for explosives for VARICOMP measurement of weapon explosive train safety and reliability. But explosives systems should be developed wherein composition control to obtain specific sensitivity and output is less critical.

1. Explosives - Sensitivity
2. Explosive trains - Safety
3. RDX/Calcium Stearate
I. Title
II. Ayres, James N.
III. Randall, Carl W., jt. author

Naval Ordnance Laboratory, White Oak, Md.
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